

Dynamic Data-Driven Event Reconstruction for Atmospheric Releases



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The release of aerosols and chemical species into the atmosphere creates a downstream plume. Our effort has been to sample the plume and then estimate the location of its source. We attempt to answer the critical questions: How much material was released? When? Where? What are the potential consequences?

Accurate estimation of the source term is essential to accurately predict plume dispersion, effectively manage the emergency response, and mitigate consequences in a case of a release of hazardous material. We have developed a capability that seamlessly integrates observational data streams with predictive models to provide probabilistic estimates of unknown source term parameters consistent with both data and model predictions. Our approach uses Bayesian inference with stochastic sampling based on Markov Chain Monte Carlo (MCMC) and Sequential

Monte Carlo (SMC) methodologies. The inverse dispersion problem is effectively addressed by reformulating it as an efficient sampling of an ensemble of predictive simulations, guided by statistical comparisons with data.

Project Goals

Our goal was to develop a flexible and adaptable data-driven event-reconstruction capability for atmospheric releases that provides:

1. quantitative probabilistic estimates of the principal source-term parameters (*e.g.*, the time-varying release rate and location);
2. predictions of increasing fidelity as an event progresses and additional data become available;
3. analysis tools for sensor network design and uncertainty studies; and
4. a model for quantification of dispersion model errors.

Our computational framework incorporates multiple stochastic algorithms, operates with a range and variety of atmospheric models, and runs on multiple computer platforms, from laptops and workstations to large-scale computing resources. We developed a multi-resolution capability for both real-time operational response and high-fidelity multi-scale applications.

Relevance to LLNL Mission

This project directly aligns with LLNL's homeland and national security missions by addressing a critical need for atmospheric release event reconstruction tools. Our efforts support the rapidly growing number of operational detection, warning, and incident characterization systems being developed and deployed by the Department of Homeland Security and the Department of Energy. The event reconstruction

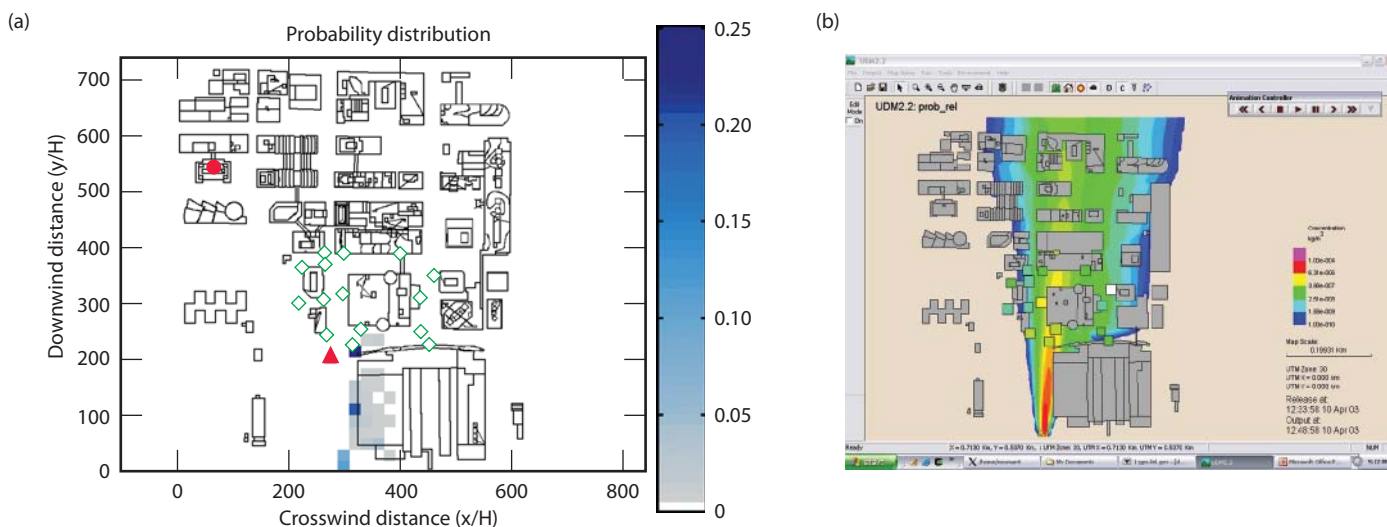


Figure 1. Example of event reconstruction for a release in an urban environment using an operational puff-dispersion model and concentration measurements from the field tracer experiment Joint Urban 2003 in Oklahoma City. (a) Color contours (blue) represent probability distribution of source location; the actual source is denoted with a triangle. (b) Color contours represent the plume from one of three likely locations (the probability distribution mode on the far South of (a)) that most closely corresponds to the actual release rate. Sensors are denoted with squares and color-coded according to measured concentrations.

capability developed by this project is targeted for integration into the next-generation National Atmospheric Release Advisory Center and a new Interagency Modeling and Atmospheric Analysis Center, based at LLNL.

FY2006 Accomplishments and Results

In FY2006 we accomplished the following:

1. implemented an operational Gaussian puff dispersion model for the simulation of urban dispersion into the MCMC capability, and tested it using data from the Joint Urban 2003 experiment in Oklahoma City (Fig. 1);
2. extended the event reconstruction capability to handle complex continental scale atmospheric releases;
3. successfully demonstrated the continental scale MCMC capability using a real world example of accidental release of radioactive material at Algeciras, Spain, in 1998 (Fig. 2);
4. developed an error quantification model for data, input parameters, and internal model output error;
5. continued developing and testing efficient stochastic sampling and convergence algorithms;
6. implemented components of a multi-resolution capability for more efficient sampling for source characterization;
7. tested a computational framework including hybrid MCMC-SMC algorithms on massively parallel platforms; and
8. continued performance enhancement of the computational framework on the range of platforms for efficient event reconstruction of complex atmospheric releases.

Related References

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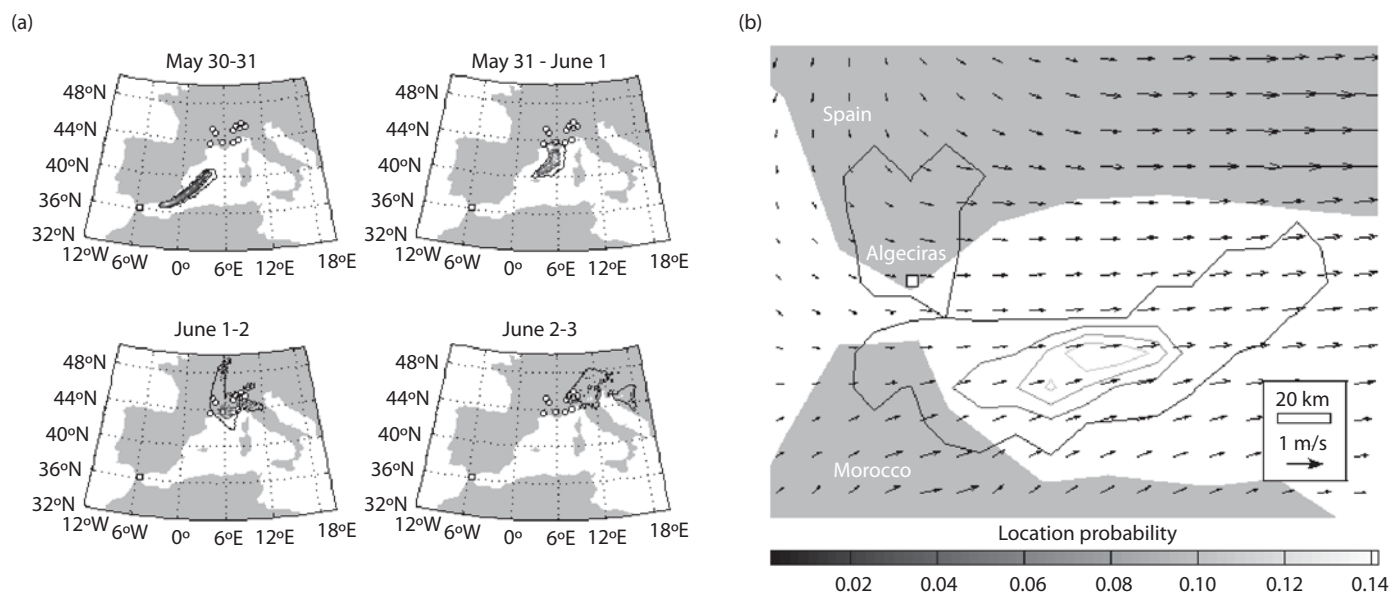


Figure 2. Example of continental scale event reconstruction using operational 3-D Lagrangian particle dispersion model and data from accidental release of Cs-137 at Algeciras, Spain, in 1998. (a) Contours represent simulated plume dispersion from the actual source over a period of four days; circles represent sensor locations. The actual source is denoted with a square. (b) Contours represent probability distribution of source location superimposed on the wind field obtained from a mesoscale model.